

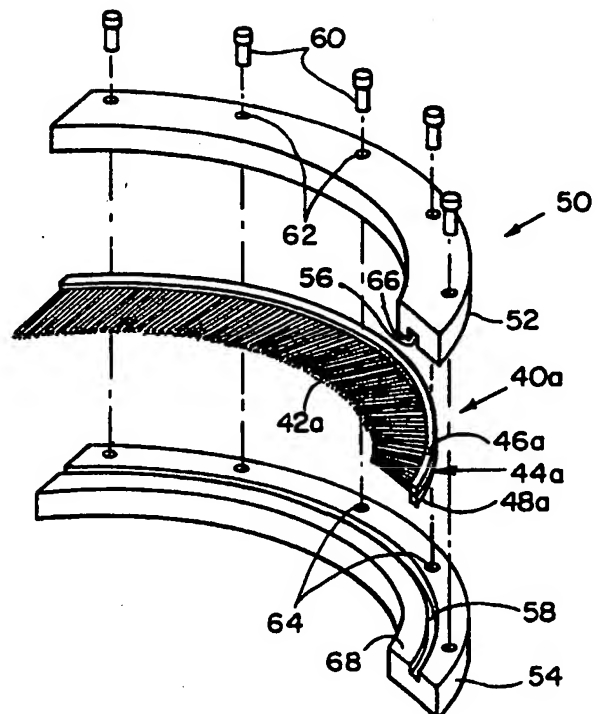


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US98/15823 <b>(22) International Filing Date:</b> 30 July 1998 (30.07.98)  <b>(30) Priority Data:</b> 08/903,457      30 July 1997 (30.07.97)      US  <b>(71) Applicant:</b> EG & G SEALOL, INC. [US/US]; 50 Sharpe Drive, Howard Industrial Park, Cranston, RI 02888 (US).  <b>(72) Inventors:</b> SHORT, John, F.; 17 Tucker Hollow Road, Scituate, RI 02857 (US). CUNNINGHAM, Matthew, D.; 21 Emerson Road, Lakeville, MA 02347 (US). DATTA, Amit; 1360 High Hawk Road, East Greenwich, RI 02818 (US).  <b>(74) Agents:</b> IANDIORIO, Joseph, S. et al.; Iandiorio & Teska, 260 Bear Hill Road, Waltham, MA 02451-1018 (US).		<b>(81) Designated States:</b> BR, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>With amended claims.</i>

**(54) Title:** IMPROVED BRUSH SEAL AND METHOD OF MAKING SAME**(57) Abstract**

A brush seal and a method of making it includes constructing a bristle strip (40) including a plurality of bristles (42) and a retainer (44) for securing the bristles; and mounting the bristle strip in a carrier (12) including front and back plates (14, 16) or washers, at least one of which plates has a groove (58) for securing and constraining the retainer to conform to the shape of the carrier.



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## IMPROVED BRUSH SEAL AND METHOD MAKING SAME

### FIELD OF INVENTION

This invention relates to an improved brush seal and method of making it, and more particularly to a brush seal in which the bristles are independently attached to a retainer and then mounted in the carrier washers or plates.

### BACKGROUND OF INVENTION

The brush seal is a device used for sealing of gas between a high and a low pressure region. Brush seals can be manufactured in both linear or curved configuration such as arcuate segments or annular rings or any other shape desired. Annular brush seals, generally used to seal rotating shafts, consist of finely packed inward pointing wire bristles mounted between two washers. These wires could also point outward in some instances. Brush seals have emerged to be a promising technology for gas-path sealing in gas turbine engines. Tests conducted by various investigators indicate that a substantial reduction in leakage can be achieved using brush seals because brush seals accommodate radial motions or wobbling of engine rotors without permanently enlarging the seal leakage area and are therefore more immune to performance degradation. Brush seals are typically manufactured by first manufacturing a number of bristle tufts (a bunch of bristles), placing the tufts between two plates or washers and welding the tufts to the washers. A tuft is one or more layers of contiguous lengths of metallic wire filaments bounded together by some means, to form a self supporting body. The method of bonding could be welding, fasteners, adhesive, or some other mechanical means. The tufts are then placed on a washer or plate by some means, closely adjacent to each other for the full length of the plate with part of the tuft projecting into the sealing side of the plate at some desired bristle or tuft angle. The plate could be a full 360° ring or a sector or portion of a circle or it could be straight. The tufts could be held to the plate by welding or by a type of holding fixture. Another circular washer or plate is then placed over the tufts with the tufts now clamped or sandwiched between the two washers or plates. Then the wire tufts are permanently welded to the washers at the O.D. or I.D. of the washers. The tufts, and two washers or plates now form an integral unit. Final

trimming of the bristles is performed at the O.D. or I.D. of the assembly.

Some of the problems associated with the above described method are the number of tufts required to make a completed brush seal, especially for the large diameter seals. The number of tufts required to manufacture a brush seal could number into the thousands. Depending upon the method used, handling a large number of tufts could be a problem. In addition, welding the bristle tufts to the washers could result in severe distortion of the retaining washers due to the amount of heat required for welding. In order to correct this, heat treatment in a holding fixture could be required to alleviate the heat distortion effect. In a typical manufacture, distortion is created from the welding of the washers to the bristle tufts. This distortion alters the location at which the bristle is captured or pinched by the washers. The radial and axial stiffness of the bristles can vary significantly from the intended design, since there is a cubic dependence on length. Ideally the bristle pack is pinched at the front plate I.D. Movement of the bristles in the region between the washers is not allowed to take place because of the pinching action of the washers. In reality, distortion of the washers due to welding pulls away the washers which relaxes the pinching action resulting in a change of bristle stiffness.

### SUMMARY OF INVENTION

It is therefore an object of this invention to provide an improved brush seal and method of making it.

It is a further object of this invention to provide such an improved brush seal and method in which the normal manufacturing distortions are virtually eliminated.

It is a further object of this invention to provide such an improved brush seal and method which eliminates the need for heat treating to remove stresses created during the welding of the bristles.

It is a further object of this invention to provide such an improved brush seal and method in which the bristles may be replaced independently of the carrier plates or washers.

It is a further object of this invention to provide such an improved brush seal and method which requires dramatically less tooling.

It is a further object of this invention to provide such an improved brush seal and

method which provides more homogeneous and uniform distribution of bristles.

It is a further object of this invention to provide such an improved brush seal and method which eliminates machining operations after final assembly.

It is a further object of this invention to provide such an improved brush seal and method which is simpler, less expensive, faster and less labor intensive.

The invention results from the realization that an improved distortion free brush seal and method for making it can be effected by independently manufacturing a bristle strip and a carrier so that the distortions undergone by the retainer as the bristles are fastened to it during fabrication are overcome by mounting it in a groove in the carrier which has been precisely made and not subject to such distortions.

This invention features a brush seal including a bristle strip having a plurality of bristles and a retainer for securing the bristles. There is a carrier including front and back plates and a groove in at least one of the plates for securing and constraining the retainer to conform to the shape of the carrier.

In a preferred embodiment the front and back plates may be integral, or they may be separate and the carrier may further include means for fastening together the plates. The groove may be formed partially in each of the plates. The means for fastening may include mechanical fastener means or weld means. The bristle strip and the carrier may be straight, curved or annular. The retainer may include a pair of retainer elements for gripping the bristles between them or it may include a single retainer element for securing the bristles. The carrier may include a plug in at least one end of each groove in the straight and curved constructions.

This invention also features a method of making a brush seal including securing a plurality of bristles to a retainer to form a bristle strip; constructing a carrier with a front and a back plate and a groove in at least one of the plates for receiving the retainer; and mounting the retainer in the groove for securing and constraining the retainer to conform to the shape of the carrier.

In a preferred embodiment the front and back plates may be separate and the mounting of the retainer may include inserting the retainer in the groove and then fastening together the plates. The groove may be formed partially in each plate. The fastening of the plates may include welding. The bristle strip and carrier may be straight,

curved or annular. Securing the bristles to the retainer may include attaching them to a single retainer element or between a pair of retainer elements. Mounting the retainer in the groove may include inserting a plug in at least one end of the groove.

### DISCLOSURE OF PREFERRED EMBODIMENT

Other objects, features and advantages will occur to those skilled in the art from the following description of a preferred embodiment and the accompanying drawings, in which:

Fig. 1 is a side elevational sectional view of a prior art brush seal;

Fig. 2 is a three-dimensional view of a finished prior art brush seal;

Fig. 3 is a view of the prior art brush seal of Figs. 1 and 2 mounted in a seal holder for a typical rotary machine such as a gas turbine used for electric power generation;

Fig. 4 is a view similar to Fig. 1 showing the distortion that occurs during the welding of the brush seal;

Fig. 5 is a straight bristle strip according to this invention;

Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 5 according to this invention;

Fig. 7 is a view similar to Fig. 5 of a curved bristle strip according to this invention;

Fig. 8 is a view similar to Figs. 6 and 7 of an annular bristle strip according to this invention;

Fig. 9 is an exploded three-dimensional view of a curved segmented brush seal according to this invention;

Figs. 10, 11 and 12 are cross-sectional diagrammatic side elevational views showing three different forms of the front and back plates and the location of the welding joint that can be used according to this invention in which a portion of the groove is located in each of the plates;

Fig. 13 is a view similar to Figs. 10-12 wherein the bristle strip includes but a single retainer element and the groove is entirely in one plate;

Fig. 14 is a view similar to Figs. 10-13 in which the carrier is formed of integral

front and back plates;

Fig. 15 is a view similar to Figs. 10-14 in which the front and back plates of the carrier are fastened by crimping instead of welding;

Fig. 16 is a three-dimensional view of one of the back plate showing the groove with closed ends; and

Fig. 17 is a three-dimensional end view of the carrier according to this invention showing a groove closed with an end plug.

There is shown in Fig. 1 a prior art brush seal 10 including a carrier 12 having a front washer or plate 14 and a back washer or plate 16. The front washer or plate is typically on the high pressure side of the seal and the back washer or plate on the low pressure side. The back plate 16 is a smaller diameter or closer to the bristle tips than front plate 14 to provide support for bristles 18 which extend slightly below the end 20 of back plate 16 and provide the actual sealing on a rotary shaft for example. The bristles are welded to each other at the end opposite the sealing end and to the front and back plates 14 and 16 at weld 22. Plates 14 and 16 are welded together so as to create a pinch point 24 at the lower end of front plate 14. This pinch point sets the length of the free bristles beyond that point and thus defines the characteristics of the seal made by those bristles. A notch 26, shown in phantom, can be provided for gripping in a holder provided in the machine which is to receive brush seal 10. Prior art brush seal 10, Fig. 1, is typically formed as an annular seal as shown in Fig. 2. Brush seal 10 is typically mounted in a holder 30, Fig. 3, which includes two clamp rings 32 and 34 held together by a series of bolts and nuts 36 circumferentially spaced about the annular clamp rings 32 and 34. Clamp ring 34 includes a salient portion 38, for example, which extends into notch 26 of seal 10 to securely grip it and hold it in place.

One of the problems with these prior art brush seals is that the washers or plates 14 and 16 become distorted or warped because of the quantity of heat they experience in order to complete the welding of the bristles to each other and to the two plates. This is made particularly difficult because the bristles, no matter how tightly compact, have air space between them which makes the interstitial heat transfer less than optimum. The warping not only can change the dimensions of the seal itself but can change the seal characteristic because the warping may cause the pinch point to vary throughout the

extent of the seal. For example, as shown in Fig. 4, plates 14 and 16 at the particular point shown in cross-section there, have separated some, leaving a gap 24' where the pinch point should be. Throughout the specification like parts have been given like numbers and similar parts similar numbers accompanied by one or more lower case letters or primes.

In accordance with this invention, however, a bristle strip 40, Fig. 5, is formed in which a plurality of bristles 42 are attached to a retainer 44. In this particular case retainer 44 includes two retainer elements 46 and 48, Fig. 6. Retainer 44 is typically a compliant rail made of either one or two retainer elements. Although bristle strip 40 is shown as having a straight configuration, it may take an arcuate or curved shape such as a segment of a circle 40a, Fig. 7, or may in fact take the form of an annulus 40b, Fig. 8. The bristle strip 40, whatever may be its shape, is installed in a carrier 50, Fig. 9, which includes front plate 52 and back plate 54 each of which contains a groove portion 56, 58, respectively. Bristle strip 40a is mounted with plates 52 and 54 by locating retainer elements 46a and 48a of retainer 44a in grooved portions 56 and 58. Plates 52 and 54 are then fastened together by means of rivets, screws or the like 60 through holes 62 in front plate 52 and corresponding holes 64 in back plate 54. In this way the bristle strip 40a which may be warped or distorted because of the manufacturing processes used to mount the bristles to one or more retainer elements 44a and 46a, such as the heat of welding, is constrained by the more substantial and stiffer plates 52 and 54 which have been precisely made and machined and have not been subject to warping or distorting forces, so that the bristle strip 40a is made to conform with whatever the dimensions and the path imposed by groove portions 56, 58 of plates 52 and 54. The pinch point of the seal is established at the location where the bristle strip 40a is captured between the inboard pinch lands 66 and 68, Fig. 9, of the front and back plates. The ID of these pinch lands 66 and 68 establishes the effective length of the bristles 42a.

Although in Fig. 9 the front and back plates 52 and 54 are shown as fastened by mechanical means such as screws or rivets, this is not a necessary limitation of the invention, for at this point they may be welded and the welds, small compared to the volume of the plates now, will not warp or distort them. For example, as shown in Figs. 10, 11 and 12, the front and back plates 52a, 54a, 52b, 54b, 52c, 54c may take various



configurations, enabling a variety of different weld positions 70, 72, 74.

Although thus far there is a portion of groove in each of the front and back plates or washers and the retainer is formed of two retainer elements with the bristles sandwiched between, this is not a necessary limitation of the invention, for as shown in Fig. 13, the back plate 54d may include the entire groove 80 and front plate 52d acts merely as a cover or holder and bristle strip 40b may include a single retainer element 48b to which the bristles 42b are attached at weld point 82. Front plate 52d may be attached to back plate 54d by any suitable means, not shown. Although thus far the front and back plates have been shown as two separate plates which must be fastened together, this is not a necessary limitation of the invention, for as shown in Fig. 14, front plate 52e and back plate 54e may be integrally formed having a single groove 84 in which retainer elements 46e, 48e of retainer 44e are located.

Carrier 50e may include one or more notches 26'', 26''', Fig. 14, for gripping in holder or mounting ring 30a. Because the carrier according to this invention and its front and back plates including the groove can be made with great precision and are not subject to distortion, the pinch point is known and unvarying. And since it is the pinch point that determines the important characteristics of the seal, the groove itself may be made to a somewhat greater tolerance to more easily, even somewhat loosely, accommodate the retainer. The front and back plates 52f, 54f, Fig. 15, may also be held together by providing an extension 90, Fig. 15, of back plate 54f that extends over and can be crimped down 90' to grip and hold front plate 52f.

When the bristle strip is made in straight or curved segments the ends of the groove may be finished or closed either by making the groove, for example, groove 58g, Fig. 16, close to but not through the end face 104, 106 of the plates 52 and 54, shown exemplified by back plate 54g in Fig. 16. A portion 100, 102 may be left at each end face 104, 106. In this way the bristle strips can be securely held in place and can be definitively finished so that segments can be added in a series end to end to form a longer curve or a complete annulus. Alternatively, as shown in Fig. 17, end plates 52h and 54h may have the groove formed by their partial grooves 56h and 58h sealed or covered by a cover 110.

The bristles may be made of Haynes 25 or Haynes 214 and typically are made of

Haynes 25. The retainer and retainer elements may be any kind of metal or suitable material preferably having some compliance, such as Inconel or stainless steel. The plates or washers of the carrier typically may be made of Inconel or stainless steel more rigid than the retainer.

Although specific features of this invention are shown in some drawings and not others, this is for convenience only as each feature may be combined with any or all of the other features in accordance with the invention.

Other embodiments will occur to those skilled in the art and are within the following claims:

What is claimed is:

**CLAIMS**

1. A brush seal comprising:  
a bristle strip including a plurality of bristles and a retainer for securing said bristles; and  
a carrier including front and back plates and a groove in at least one of said plates for securing and constraining said retainer to conform to the shape of the carrier.
2. The brush seal of claim 1 in which said front and back plates are integral.
3. The brush seal of claim 1 in which said front and back plates are separate and said carrier further includes means for fastening together said plates.
4. The brush seal of claim 1 in which said groove is formed partially in each of said plates.
5. The brush seal of claim 3 in which said means for fastening includes mechanical fastener means.
6. The brush seal of claim 3 in which said means for fastening includes weld means.
7. The brush seal of claim 1 in which said bristle strip and said carrier are straight.
8. The brush seal of claim 1 in which said bristle strip and said carrier are curved.

9. The brush seal of claim 1 in which said bristle strip and said carrier are annular.
10. The brush seal of claim 1 in which said retainer includes a pair of retainer elements for gripping said bristles between them.
11. The brush seal of claim 1 in which said retainer includes a retainer element for securing said bristles.
12. The brush seal of claim 7 in which said carrier includes a plug in at least one end of said groove.
13. The brush seal of claim 8 in which said carrier includes a plug in at least one end of said groove.
14. The brush seal of claim 1 in which said bristle strip is removably replaceable in said carrier.
15. A method of making a brush seal comprising:
  - securing a plurality of bristles to a retainer to form a bristle strip;
  - constructing a carrier with a front and a back plate with a groove in at least one of the plates for receiving the retainer; and
  - mounting the retainer in the groove for securing and constraining the retainer to conform to the shape of the carrier.
16. The method of claim 15 in which the front and back plates are separate and mounting the retainer includes inserting the retainer in the groove and fastening together the plates.

17. The method of claim 15 in which the groove is formed partially in each plate.
18. The method of claim 15 in which fastening the plates includes welding.
19. The method of claim 15 in which the bristle strip and carrier are straight.
20. The method of claim 15 in which the bristle strip and carrier are curved.
21. The method of claim 15 in which the bristle strip and carrier are annular.
22. The method of claim 15 in which securing the bristles to the retainer includes attaching them to a single retainer element.
23. The method of claim 15 in which securing the bristles to the retainer includes attaching them between a pair of retainer elements.
24. The method of claim 19 in which mounting the retainer in the groove includes inserting a plug in at least one end of the groove.
25. The method of claim 20 in which mounting the retainer in the groove includes inserting a plug in at least one end of the groove.

**AMENDED CLAIMS**

[received by the International Bureau on 4 January 1999 (04.01.99);  
original claims 1,12,13,15,24 and 25 amended; new claims 26-28  
added; remaining claims unchanged (4 pages)]

1.       A brush seal comprising:  
          a bristle strip including a plurality of bristles and a retainer for  
          securing said bristles; and  
          a carrier including front and back plates and a groove in at least one  
          of said plates for securing and constraining said retainer to conform to the shape of the  
          carrier and for regulating the effective length of said plurality of bristles.
2.       The brush seal of claim 1 in which said front and back plates are  
          integral.
3.       The brush seal of claim 1 in which said front and back plates are  
          separate and said carrier further includes means for fastening together said plates.
4.       The brush seal of claim 1 in which said groove is formed partially  
          in each of said plates.
5.       The brush seal of claim 3 in which said means for fastening includes  
          mechanical fastener means.
6.       The brush seal of claim 3 in which said means for fastening includes  
          weld means.
7.       The brush seal of claim 1 in which said bristle strip and said carrier  
          are straight.
8.       The brush seal of claim 1 in which said bristle strip and said carrier  
          are curved.
9.       The brush seal of claim 1 in which said bristle strip and said carrier

are annular.

10. The brush seal of claim 1 in which said retainer includes a pair of retainer elements for gripping said bristles between them.

11. The brush seal of claim 1 in which said retainer includes a retainer element for securing said bristles.

12. The brush seal of claim 7 in which said carrier includes a groove cover at at least one end of said groove.

13. The brush seal of claim 8 in which said carrier includes a groove cover at at least one end of said groove.

14. The brush seal of claim 1 in which said bristle strip is removably replaceable in said carrier.

15. A method of making a brush seal comprising:  
securing a plurality of bristles to a retainer to form a bristle strip;  
constructing a carrier with a front and a back plate with a groove in at least one of the plates for receiving the retainer; and  
mounting the retainer in the groove for securing and constraining the retainer to conform to the shape of the carrier and for regulating the effective length of said plurality of bristles.

16. The method of claim 15 in which the front and back plates are separate and mounting the retainer includes inserting the retainer in the groove and fastening together the plates.

17. The method of claim 15 in which the groove is formed partially in each plate.

18. The method of claim 15 in which fastening the plates includes welding.
19. The method of claim 15 in which the bristle strip and carrier are straight.
20. The method of claim 15 in which the bristle strip and carrier are curved.
21. The method of claim 15 in which the bristle strip and carrier are annular.
22. The method of claim 15 in which securing the bristles to the retainer includes attaching them to a single retainer element.
23. The method of claim 15 in which securing the bristles to the retainer includes attaching them between a pair of retainer elements.
24. The method of claim 19 in which mounting the retainer in the groove includes applying a groove cover at at least one end of the groove.
25. The method of claim 20 in which mounting the retainer in the groove includes applying a groove cover at at least one end of the groove.
26. A brush seal comprising:  
a bristle strip including a plurality of bristles and a retainer for securing said bristles; and  
a carrier including front and back plates and a groove in at least one of said plates for securing and constraining said retainer to conform to the shape of the carrier, where said groove is formed partially in each of said plates.



27. A method of making a brush seal comprising:  
securing a plurality of bristles to a retainer to form a bristle strip;  
constructing a carrier with a front and a back plate with a groove in  
at least one of the plates for receiving the retainer, where said groove is formed partially  
in each plate; and  
mounting the retainer in the groove for securing and constraining  
the retainer to conform to the shape of the carrier.
28. A brush seal comprising:  
a bristle strip including a plurality of bristles and a retainer for  
securing said bristles;  
a carrier including front and back plates and a groove in at least one  
of said plates for securing and constraining said retainer to conform to the shape of said  
carrier; and  
a holder radially located about said carrier.

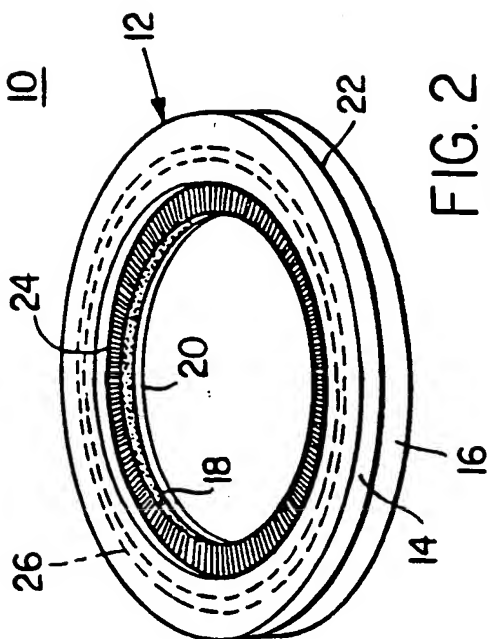


FIG. 2  
Prior Art

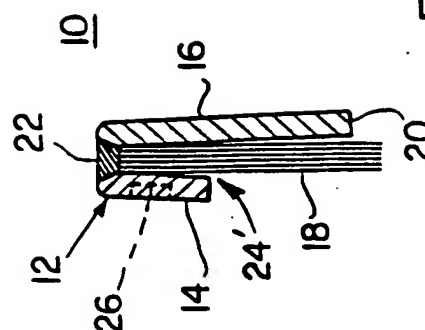


FIG. 4  
Prior Art

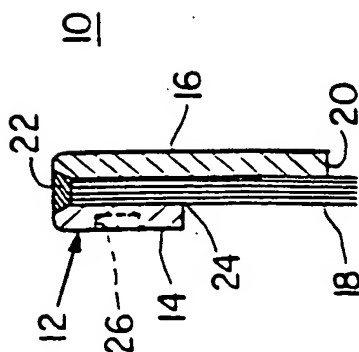


FIG. 1  
Prior Art

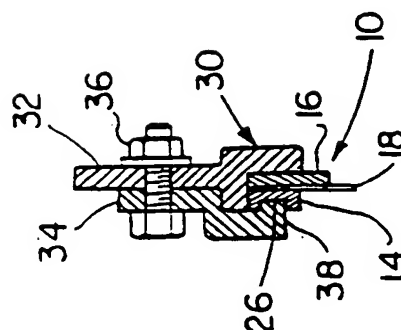


FIG. 3  
Prior Art

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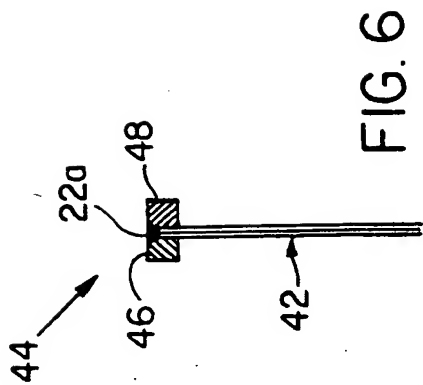


FIG. 6

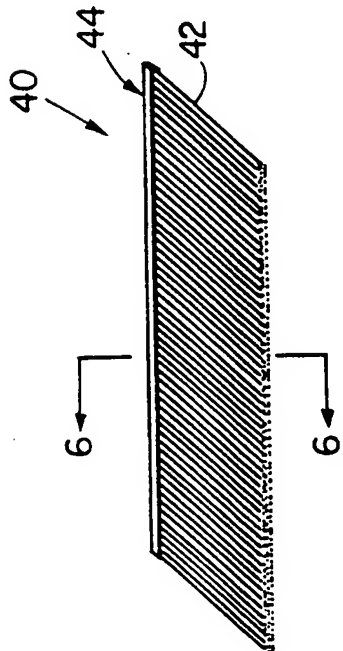


FIG. 5

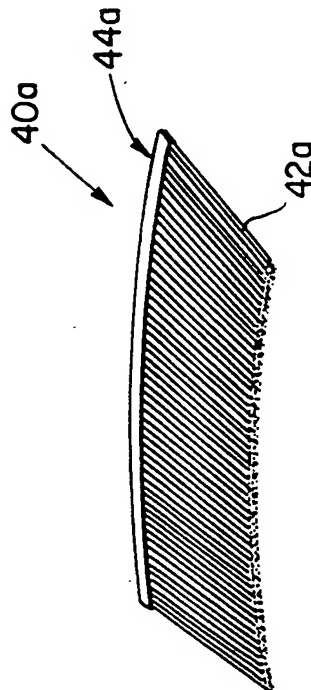


FIG. 7

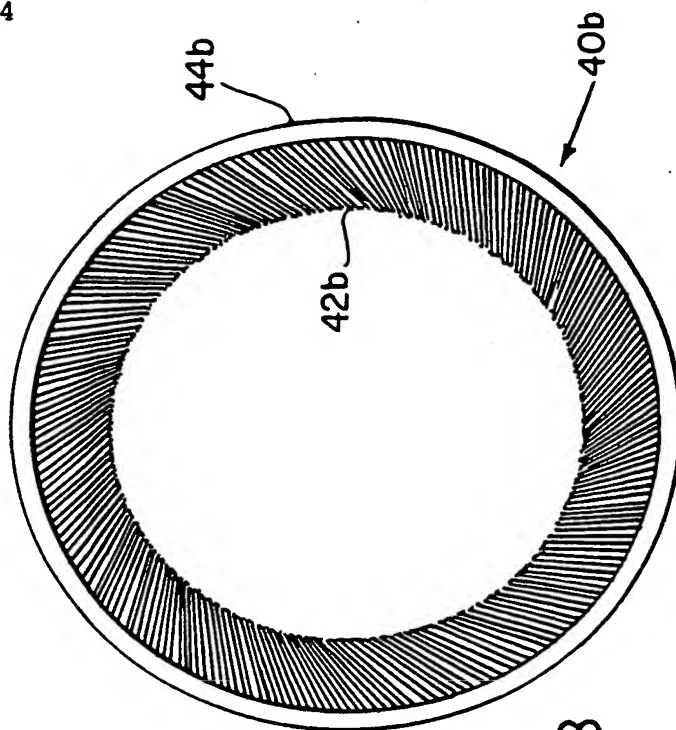


FIG. 8

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FIG. 9

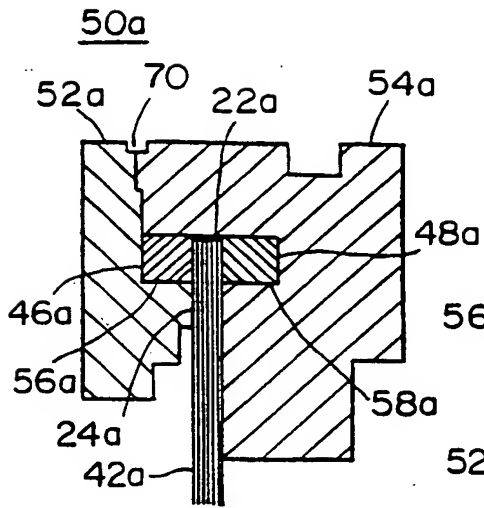
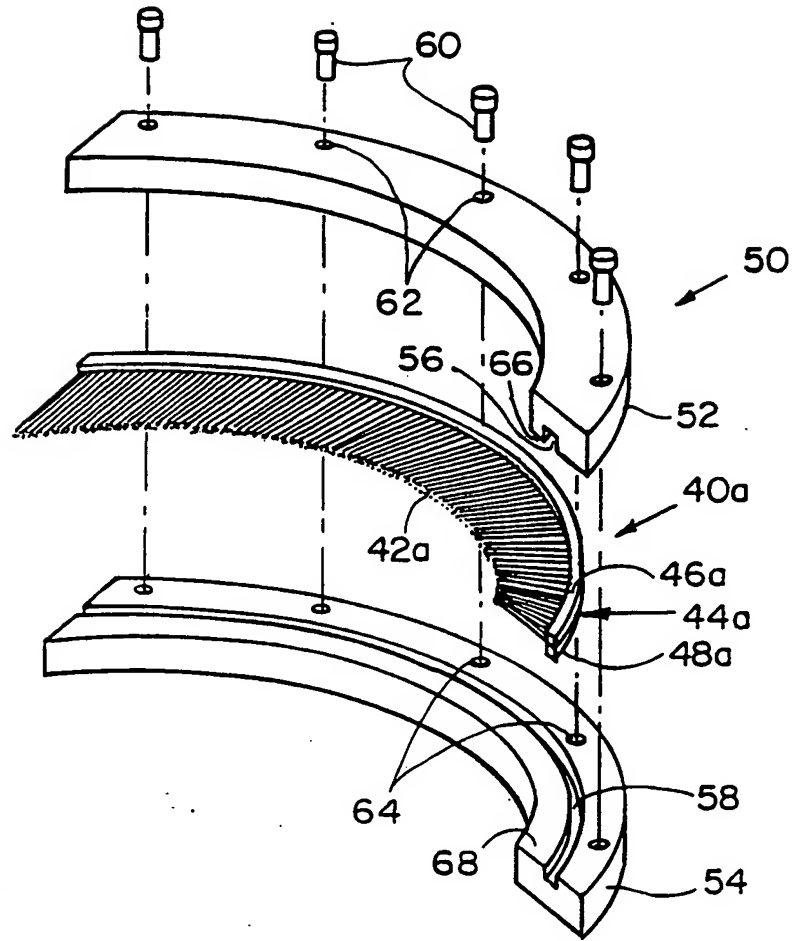


FIG. 10

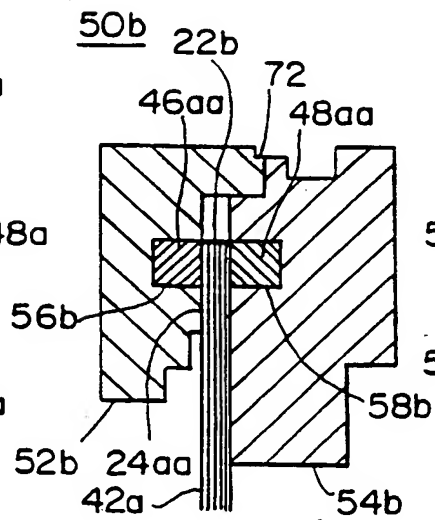


FIG. 11

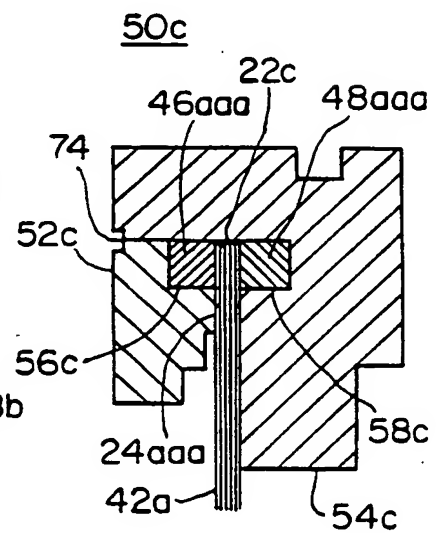


FIG. 12

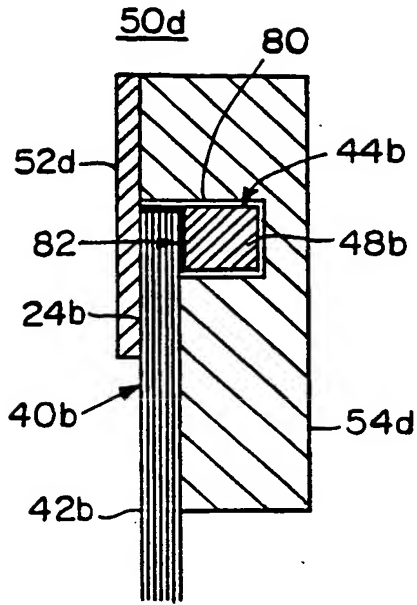


FIG. 13

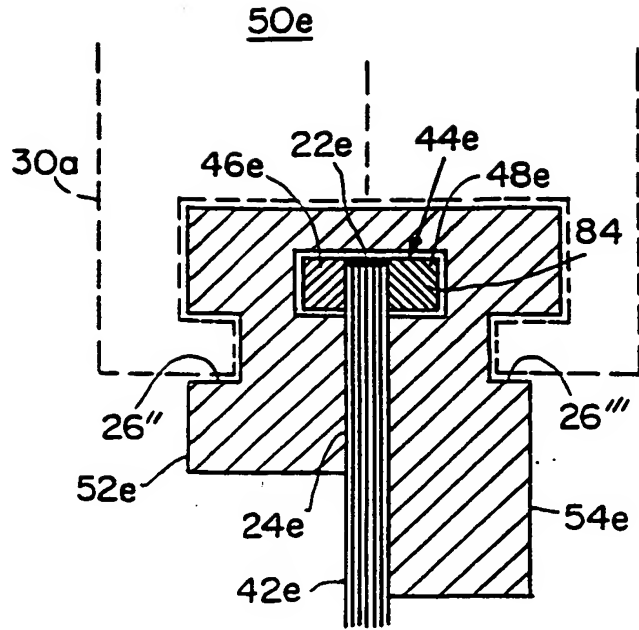


FIG. 14

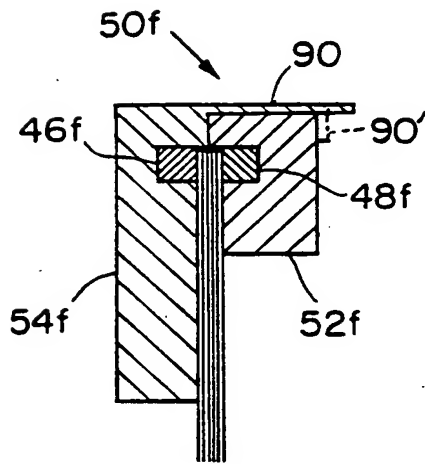


FIG. 15

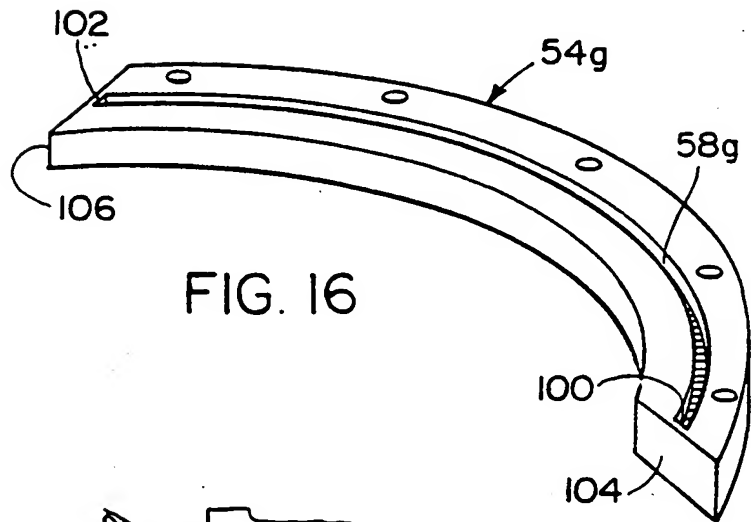


FIG. 16

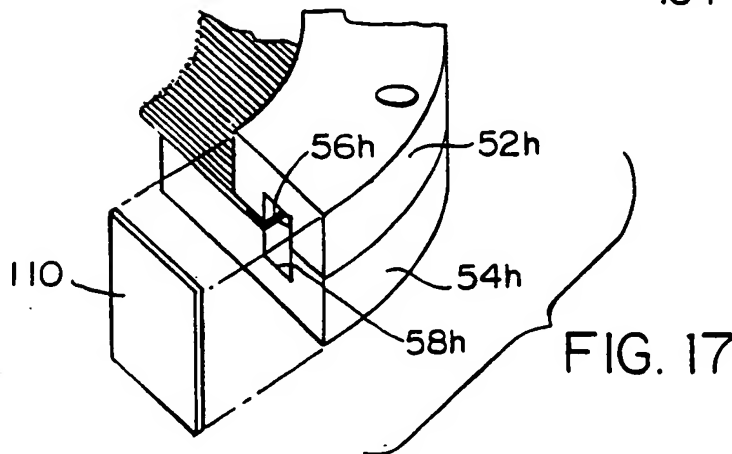


FIG. 17

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/15823

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : F01D 11/02

US CL : 277/255

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 277/255

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --	US 5,090,710 A (FLOWER) 25 FEBRUARY 1992 (25/02/92), SEE ENTIRE DOCUMENT.	1, 3, 5, 7-11, 14-17, AND 19-23 -----
Y		1, 2, 6, 18
Y, P	US 5,704,760 A (BOUCHARD ET AL) 06 JANUARY 1998 (06/02/98), SEE ENTIRE DOCUMENT	1
Y	US 885,032 A (DE FERRANTI) 21 APRIL 1908 (21/04/08), SEE ENTIRE DOCUMENT	2
Y	GB 2,214,998 A (REISINGER ET AL) 13 SEPTEMBER 1989 (13/09/89), SEE ENTIRE DOCUMENT.	6, 18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

08 SEPTEMBER 1998

Date of mailing of the international search report

06 NOV 1998

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